# 3.6 Further Mechanics and Thermal Physics: Test Pack

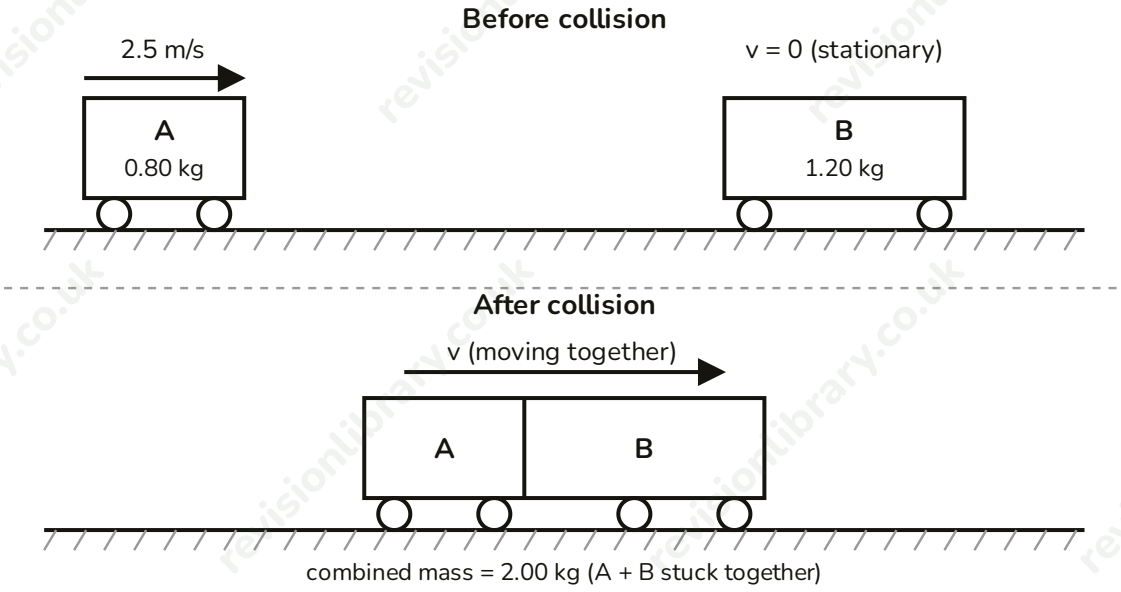
AQA 7408 · Calculator allowed · about 65 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

**Answer ALL questions. Show all your working.**

**1** In a laboratory demonstration, trolley A of mass 0.80 kg moves at a constant velocity of 2.5 m/s on a frictionless track towards stationary trolley B of mass 1.20 kg. The trolleys collide and stick together, moving off as one combined object.




**(a)** Define momentum, and state the principle of conservation of momentum. **(2)**

**(b)** Calculate the momentum of trolley A before the collision. **(2)**

**(c)** Calculate the common velocity of the two trolleys immediately after the collision. **(3)**

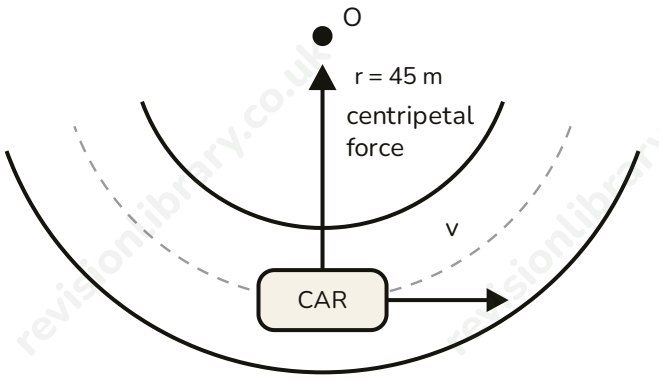
**(d)** Calculate the total kinetic energy of the system before and after the collision, and use your values to determine whether the collision is elastic. **(3)**

**(Total for Question 1 is 10 marks)**


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**2** A car of mass 1200 kg drives at constant speed around a flat circular bend of radius 45 m. Use the Physics Equations Sheet where needed ($a = v^2/r$ for centripetal acceleration). Take $g = 9.81$ m/s$^2$.

Top view




**(a)** State what is meant by angular velocity, and calculate the angular velocity of a wheel on the car that completes one full rotation in 28 ms ($2.8 \times 10^{-2}$ s). **(2)**

**(b)** The car travels around the bend at a constant speed of 15 m/s. Using $a = v^2/r$, calculate the centripetal acceleration of the car, and hence the centripetal force acting on it. **(4)**

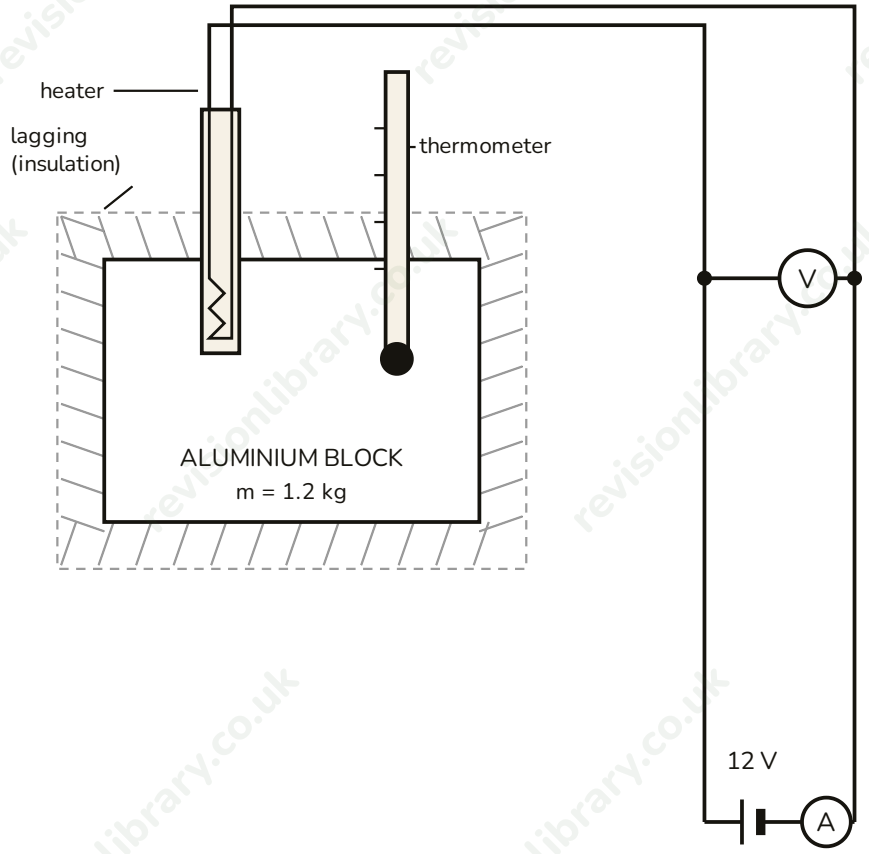
**(c)** The centripetal force is provided entirely by friction between the tyres and the road, with coefficient of friction $\mu = 0.65$ between tyre and road. Calculate the maximum speed at which the car can take the bend without skidding. **(3)**

**(d)** Explain, in terms of Newton's laws, why a passenger sitting on the outside of the turn feels pushed outwards against the car door as the car goes round the bend. **(2)**

**(Total for Question 2 is 11 marks)**


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**3** Practical investigation. An aluminium block of mass 1.2 kg has an electrical heater and a thermometer embedded in holes drilled into it, and is connected to a 12 V supply drawing a constant current of 4.0 A.




**(a)** Describe how this apparatus could be used to determine the specific heat capacity of aluminium, including how heat losses to the surroundings are minimised. **(3)**

**(b)** In one run, the temperature of the block rises from 18.0°C to 42.5°C in 15 minutes. Using Q = VIt and Q = mc x (temperature change), calculate the value obtained for the specific heat capacity of aluminium from this experiment. **(4)**


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**(c)** The accepted value for the specific heat capacity of aluminium is 900 J/(kg K). Suggest one reason for the difference between this accepted value and the value calculated in part (b), and suggest one improvement to the experiment that would reduce this effect. **(2)**

**(Total for Question 3 is 9 marks)**

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**4** This question tests core definitions in further mechanics and thermal physics.

**(a)** Define angular velocity for an object moving in a circle. **(1)**

**(b)** State the defining condition for an object to be moving with simple harmonic motion. **(1)**

**(c)** State what is meant by the internal energy of a system. **(1)**

**(Total for Question 4 is 3 marks)**

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**5** A fixed mass of an ideal gas has an initial pressure of $1.0 \times 10^5$ Pa, volume $2.4 \times 10^{-3}$ $m^3$ and temperature 290 K. The gas is compressed to a volume of $1.6 \times 10^{-3}$ $m^3$ and heated to a temperature of 350 K. The molar gas constant R = 8.31 J/(mol K).

**(a)** Use the combined gas law to calculate the new pressure of the gas. **(4)**

**(b)** Calculate the number of moles of gas present. **(3)**

**(c)** Given that the molar mass of the gas is 0.032 kg/mol, calculate the root-mean-square speed of the gas molecules at the initial temperature of 290 K, using $c(rms) = \sqrt{3RT/M}$. **(4)**

**(Total for Question 5 is 11 marks)**


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# Mark scheme · 3.6 Further Mechanics and Thermal Physics: Test Pack

## Question 1

(a) momentum = mass x velocity (a vector quantity), oe **B1**

(a) in a closed system (no external resultant force), the total momentum before an interaction equals the total momentum after the interaction, oe **B1**

**(a) Answer: Momentum = mass x velocity; total momentum of a closed system is conserved (unchanged) provided no external resultant force acts.**

(b) correct substitution into p = mv **M1**

(b) p = 2.0 kg m/s, cao **A1**

**(b) Answer: 2.0 kg m/s**

(c) conservation of momentum applied: total momentum before = total momentum after, oe **M1**

(c) combined mass = 0.80 + 1.20 = 2.00 kg used correctly, ft from (b) **M1**

(c) v = 1.0 m/s, in the original direction of motion of A, cao **A1**

**(c) Answer: 1.0 m/s (in the direction A was originally travelling)**

(d) KE before = 1/2 x 0.80 x $2.5^2$ = 2.5 J **M1**

(d) KE after = 1/2 x 2.00 x $1.0^2$ = 1.0 J, ft from (c) **M1**

(d) conclusion: KE has decreased (from 2.5 J to 1.0 J), so the collision is not elastic (kinetic energy is not conserved), oe **A1**

**(d) Answer: KE before = 2.5 J; KE after = 1.0 J; collision is inelastic (1.5 J of KE is lost, e.g. to heat and sound)**

## Question 2

(a) angular velocity is the rate of change of angular displacement (angle turned per unit time), unit rad/s, oe **B1**

(a) ω = 2 x π / 0.028 = 224 rad/s (awrt), using ω = 2pi/T **A1**

**(a) Answer: 224 rad/s (3 s.f.)**

(b) correct substitution into a = $v^2/r$ **M1**

(b) a = 5.0 $m/s^2$, cao **A1**

(b) F = ma used with the value of a found, ft **M1**

(b) F = 6000 N, cao **A1**

**(b) Answer: a = 5.0 $m/s^2$, F = 6000 N**

(c) friction force provides centripetal force: μ x m x g = m x $v^2/r$, oe **M1**

(c) rearranged correctly to v = $\sqrt{\&\mu; x g x r}$ **M1**

(c) v = 16.9 m/s (awrt), cao **A1**

**(c) Answer: 16.9 m/s (3 s.f.)**

(d) the passenger's inertia tends to keep them moving in a straight line (Newton's first law), oe **B1**

(d) the door exerts an inward centripetal force on the passenger; by Newton's third law the passenger exerts an equal outward force on the door, not on themselves, oe **B1**

**(d) Answer: The passenger's inertia tends to keep them moving in a straight line, so they press against the outside door as the car turns. The door exerts an inward centripetal force on the passenger. The equal and opposite outward reaction force exerted by the passenger acts on the door.**

## Question 3

(a) lag (insulate) the block with insulating material to minimise heat loss to the surroundings, oe **B1**

(a) record the initial temperature, switch on the heater for a measured time t while recording the current I and potential difference V, then record the final (maximum) temperature reached, oe **B1**

(a) calculate the electrical energy supplied Q = VIt and use Q = mc x (temperature change) to find c, oe **B1**

**(a) Answer: Insulate (lag) the block to reduce heat loss; measure initial and final temperature while supplying a known electrical energy Q = VIt over a measured time; calculate c from Q = mc x deltaT.**

(b) Q = VIt = 12 x 4.0 x 900 = 43200 J (using t = 15 x 60 = 900 s) **M1**

(b) temperature change = 42.5 - 18.0 = 24.5 K (or °C) **M1**

(b) correct rearrangement, c = Q/(m x deltaT), with correct substitution, ft **M1**

(b) c = 1470 J/(kg K) (awrt), cao, unit given **A1**

**(b) Answer: 1470 J $kg^{-1}$ $K^{-1}$ (3 s.f.)**

(c) some of the electrical energy supplied is lost to the surroundings (e.g. by conduction, convection or radiation from the block, heater leads or thermometer) rather than all going into raising the temperature of the block, so the calculated c (based on the full electrical energy supplied) is an overestimate, oe **B1**

(c) suitable improvement, e.g. improve the lagging/insulation around the block, or apply a cooling correction (continue timing/temperature readings after switching off the heater and correcting for heat lost), oe **B1**

**(c) Answer: Heat is lost to the surroundings rather than fully raising the block's temperature, giving an overestimate of c; improve insulation (better lagging) or use a cooling correction to account for the heat lost.**

## Question 4

(a) the rate of change of angle (angular displacement) with respect to time oe, units rad/s **B1**

**(a) Answer: The rate of change of angular displacement with respect to time.**

(b) acceleration is directly proportional to displacement from a fixed point and is always directed towards that point (opposite in direction to the displacement) oe **B1**

**(b) Answer: Acceleration is proportional to displacement from a fixed equilibrium point, and always directed towards that point.**

(c) the sum of the randomly distributed kinetic and potential energies of the particles (molecules/atoms) that make up the system oe **B1**

**(c) Answer: The sum of the randomly distributed kinetic and potential energies of all the particles in a system.**


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## Question 5

(a) quote P1V1/T1 = P2V2/T2 **M1**

(a) rearrange to P2 = P1 V1 T2 / (T1 V2) **M1**

(a) substitute P2 = (1.0 x $10^5$ x 2.4 x $10^{-3}$ x 350) / (290 x 1.6 x $10^{-3}$) **M1**

(a) P2 = 1.81 x $10^5$ Pa cao **A1**

**(a) Answer: 1.81 x $10^5$ Pa**

(b) use n = P1V1/(RT1) **M1**

(b) substitute n = (1.0 x $10^5$ x 2.4 x $10^{-3}$) / (8.31 x 290) **M1**

(b) n = 0.0996 mol cao **A1**

**(b) Answer: 0.0996 mol**

(c) quote c(rms) = $\sqrt{3RT/M}$ **M1**

(c) substitute c(rms) = $\sqrt{(3 \times 8.31 \times 290) / 0.032}$ **M1**

(c) carry out the calculation inside the square root: 7229.7/0.032 = 225,928 **M1**

(c) c(rms) = 475 m/s cao **A1**

**(c) Answer: 475 m/s**


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